

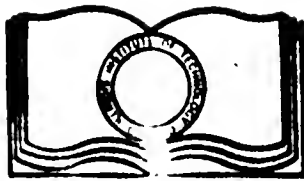
Effects of Iron Conduits
On Line Drop

F. A. Putt
B. E. Beamer

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Putt, F. A.

An investigation of the
effects of iron conduits on

AN INVESTIGATION OF THE
EFFECTS OF IRON CONDUITS ON LINE DROP.

A THESIS PRESENTED

BY

F. A. PUTT.

B. E. BEAMER.

TO THE
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FOR THE DEGREE
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BACHELOR OF SCIENCE IN ELECTRICAL
ENGINEERING
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AN INVESTIGATION OF THE
EFFECTS OF IRON CONDUITS ON LINE DROP.

The tendency in central station practice has been to decrease the cost of generation of energy ,and to cut down the losses wherever it was possible so that at the present time the attention has been directed to the investigation of and diminishing , of any loss which decreases the efficiency and output of the central station. In large central stations a loss or leakage of energy amounting to only a fraction of one per cent of the total power developed , will in the course of a year mean a loss of hundreds and sometimes thousands of dollars to the company. This fact has led to the investigation of losses in the transmission of energy , and in connection with this the effect of iron conduit on line drop when the iron conduit is used in alternating current work.

It is current practice in central stations to place the leads from the generators, rotary converters , and transformers to the switchboard in iron conduits. This is also true of substation wiring as well as of the wiring in large buildings.

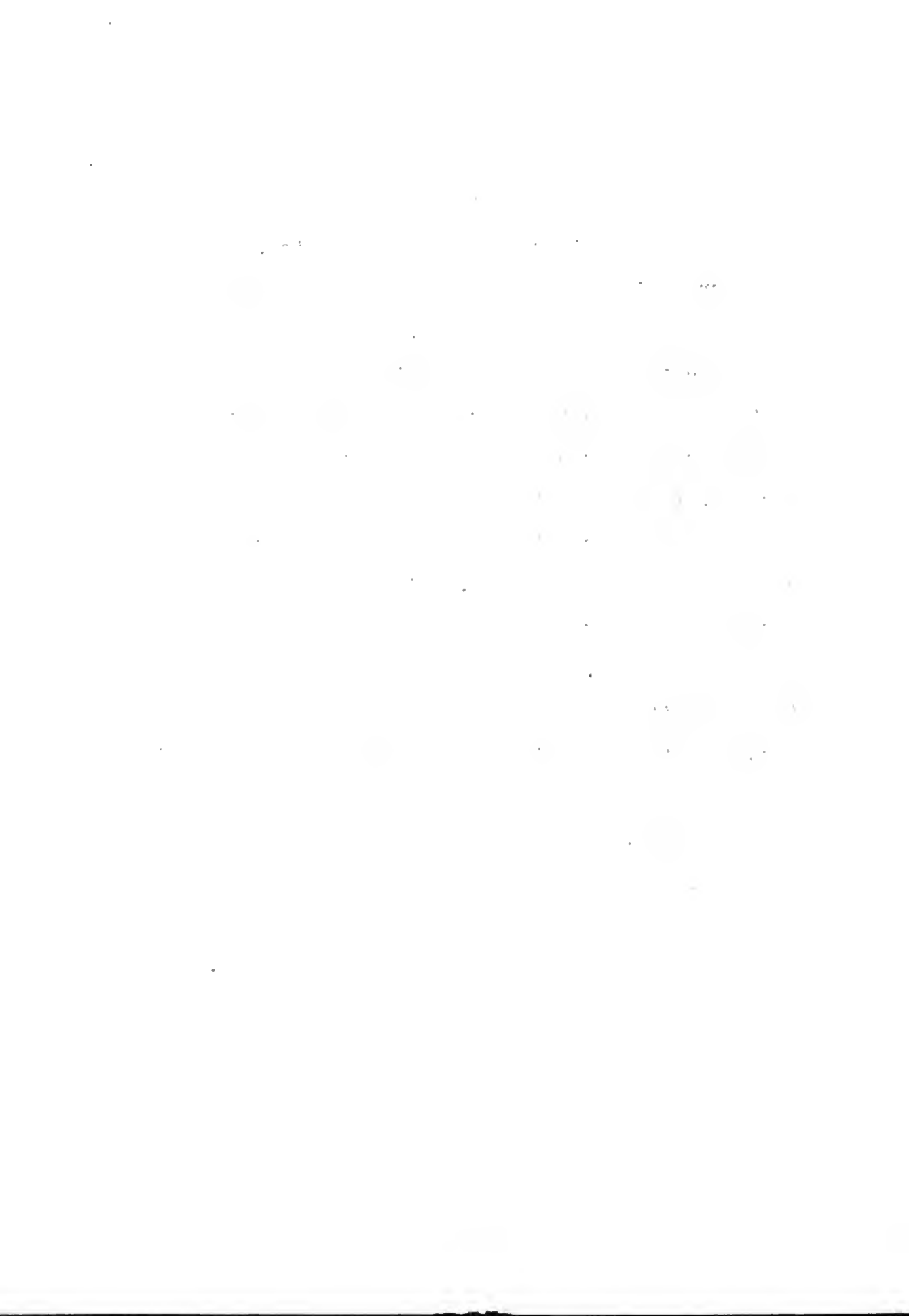
It is the object of this paper to investigate and discuss the effect of the iron conduit on the line drop and experimentally determine the magnitude of the losses due to it.

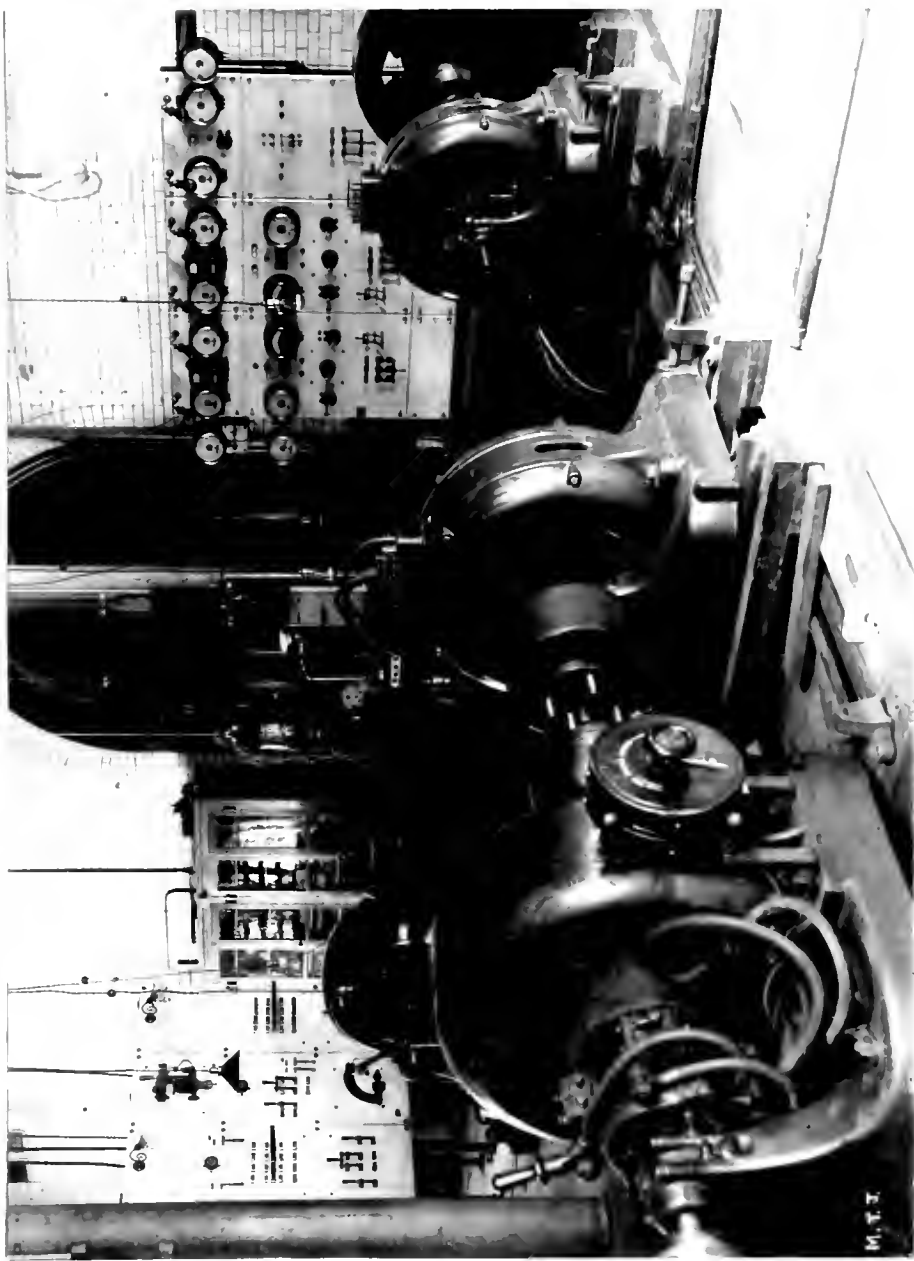
bn .

It is a well known fact that when direct current is used the iron pipe or conduit would have no effect on the line drop and the only difference of potential would be caused by the ohmic resistance of the wire. When alternating current is used there maybe a noticeable drop due to the self-induction of the wire.

One of the fundamental principles of electricity is that when a conductor carries an electric current there is a field set up around that conductor proportional to the current. Any change in this field will produce a counter electromotive force in the conductor proportional to the rate of change of the flux. This counter- electromotive force acts as a resistance opposing the flow of the current in the conductor. When the conductor is enclosed in the iron conduit the flux is increased due to the increased permeability of the iron over air; thereby increasing the counter- electromotive force and thus causing a larger drop over the wire.

Experiments along this line were carried on with single and three phase currents under different conditions of load, variation of frequency , and conduits.





Description of The Apparatus Used.

The following machines and instruments were used in obtaining the data for this paper. The alternating current both single and three-phase , for fifty(50) , fifty-five (55) , and sixty (60) cycles was obtained from a General Electric Company three-phase alternating current generator # 65447- six pole -- giving seventy-two (72) amperes at twelve hundred (1200) revolutions per minute and one hundred and twenty (120) volts at full load. The alternator was driven by a direct - connected Crocker- Wheeler motor # 265 rated for twenty - six (26) horse power at one thousand twenty-five revolutions per minute ; taking one hundred and ninety (190) amperes at one hundred and fifteen (115) volts. The generator was excited by current from a Westinghouse compound direct current generator # 208697 rated at one hundred and twenty-five (125) volts -- one hundred and twenty (120) amperes at one thousand fifty (1050) revolutions per minute, driven a direct - connected twenty-six (26) horse power Crocker- Wheeler motor. This method of excitation afforded good regulation for all condition of load and frequency.

For all data at twenty-five and thirty cycles, single and three-phase currents was taken on a direct-driven Wood alternator rated at thirty horse power , one hundred and ten (110) volts and five hundred (500) revolutions per minute.

The first part of the paper is devoted to the study of the properties of the function $f(x)$ defined by the equation $f(x) = \int_0^x f(t) dt$. It is shown that $f(x)$ is a constant function. The second part of the paper is devoted to the study of the properties of the function $g(x)$ defined by the equation $g(x) = \int_0^x g(t) dt$. It is shown that $g(x)$ is a constant function. The third part of the paper is devoted to the study of the properties of the function $h(x)$ defined by the equation $h(x) = \int_0^x h(t) dt$. It is shown that $h(x)$ is a constant function. The fourth part of the paper is devoted to the study of the properties of the function $k(x)$ defined by the equation $k(x) = \int_0^x k(t) dt$. It is shown that $k(x)$ is a constant function. The fifth part of the paper is devoted to the study of the properties of the function $l(x)$ defined by the equation $l(x) = \int_0^x l(t) dt$. It is shown that $l(x)$ is a constant function. The sixth part of the paper is devoted to the study of the properties of the function $m(x)$ defined by the equation $m(x) = \int_0^x m(t) dt$. It is shown that $m(x)$ is a constant function. The seventh part of the paper is devoted to the study of the properties of the function $n(x)$ defined by the equation $n(x) = \int_0^x n(t) dt$. It is shown that $n(x)$ is a constant function. The eighth part of the paper is devoted to the study of the properties of the function $o(x)$ defined by the equation $o(x) = \int_0^x o(t) dt$. It is shown that $o(x)$ is a constant function. The ninth part of the paper is devoted to the study of the properties of the function $p(x)$ defined by the equation $p(x) = \int_0^x p(t) dt$. It is shown that $p(x)$ is a constant function. The tenth part of the paper is devoted to the study of the properties of the function $q(x)$ defined by the equation $q(x) = \int_0^x q(t) dt$. It is shown that $q(x)$ is a constant function.

The load was obtained by means of an incandescent lamp rack and so assured a non-inductive load .

Thomson alternating current ammeters and voltmeters calibrated for this experiment were used to measure the current and pressure respectively. A Weston wattmeter was used to measure the power consumed and a Queen electro-dynamometer calibrated to read in volts was used to measure the drop over the wire in the pipes.

The different frequencies were obtained by running the alternators at different speeds . A Weston tachometer was used to indicate the speed.

1. The first part of the paper is devoted to a general discussion of the problem of the existence of solutions of the system of equations (1) for arbitrary values of the parameters α and β . It is shown that the system has solutions for all values of the parameters α and β if the function $f(x)$ is continuous and has a bounded derivative. The second part of the paper is devoted to a detailed study of the properties of the solutions of the system (1) for arbitrary values of the parameters α and β . It is shown that the solutions of the system (1) are unique and depend continuously on the parameters α and β . The third part of the paper is devoted to a study of the asymptotic properties of the solutions of the system (1) for large values of the parameters α and β . It is shown that the solutions of the system (1) approach zero as the parameters α and β approach infinity.



SCHEME #1 SINGLE PHASE.

Single Phase.

Method:-

The authors first investigated the drop over the wire in the conduit when single phase current was used. The apparatus was connected as shown in the scheme (#1) on the preceeding page. The lamp rack used for the load was connected in series with the wire in the pipe, and an ammeter and the series coil of the wattmeter. The voltmeter was connected across the line, reading the drop over the wire in the pipes, and the lamp rack. The pressure coil of the wattmeter was connected to the same points as the voltmeter.

The electro-dynamometer was connected to read the drop over the wire in the pipe. Eighty feet of (#14) number fourteen rubber covered copper wire was used being doubled in forty feet of one and one eighth inch iron conduit.

Runs were taken with the wire in the pipe for twenty-five, thirty, fifty, fifty-five, and sixty cycles. The voltage was maintained constant at one hundred and ten (110) volts over the lamps. Simultaneous readings were taken of the drop over the wire in the pipe by means of the dynamometer and watts consumed in the circuit, by the wattmeter for loads varying from ten to fifty amperes by five ampere steps. The wire was then removed from the iron conduit and similar readings taken for the same frequencies and loads.

Single-phase Data. Wire in the Pipe.

60 cycles.			55 cycles.			50 cycles.		
Amp.	K.W.	Volts.	Amp.	K.W.	Volts.	Amp.	K.W.	Volts.
11.5.	1.1	.8	11.5	1.1	.8	10.4	1.1	.67
15.5	1.6	1.32	15.5	1.6	1.32	14.5	1.6	1.3
19.5	2.2	1.8	18.5	2.1	1.7	18.4	2.1	1.74
24.	2.6	2.2	22.3	2.62	2.14	23.	2.6	3.2
29.	3.2	2.72	28.	3.2	2.6	27.4	3.15	2.6
33.	3.6	3.15	32.	3.7	3.	32.	3.7	3.03
37.5	4.25	3.65	36.2	4.2	3.5	36.5	4.2	3.5
41.5	4.8	4.15	40.5	4.75	3.95	40.5	4.75	3.98
46.	5.2	4.55	45.	5.25	4.5	45.	5.2	4.48
48.5	5.5	4.9	49	5.72	4.9	49.	5.7	4.87

30 cycles.			25 cycles.		
Amp.	K.W.	Volts.	Amp.	K.W.	Volts.
10.5	1.	.8	10.5	1.	.66
15.	1.5	1.3	14.8	1.5	1.25
19.2	2.08	1.8	19.	2.1	1.8
24.	2.6	2.2	24.	2.62	2.2
29.	3.14	2.7	28.8	3.18	2.65
33.4	3.72	3.14	34.	3.63	3.1
38.	4.22	3.6	38.	4.2	3.7
42.	4.73	4.1			
46.5	5.28	4.6			

Single- phase Data . Wire out of Pipe.

60 cycles.			55 cycles.			50 cycles.		
Amp.	K.W.	Volts.	Amp.	K.W.	Volts.	Amp.	K.W.	Volts.
10.5	1.1	.5	12.5	1.2	.64	12.5	1.	.9
14.8	1.52	1.2	16.5	1.5	1.3	16.5	1.55	1.34
19.	2.05	1.64	20.8	2.05	1.74	20.7	2.1	1.73
24.	2.62	2.1	25.	2.6	2.12	25.	2.6	2.15
29.	3.2	2.55	30.	3.15	2.6	30.	3.13	2.54
33.	3.7	2.94	34.2	3.65	3.	34.2	3.68	3.
37.5	4.2	3.4	38.8	4.15	3.47	39.	4.21	3.55
42.4	4.6	3.84	43.5	4.66	3.9	43.2	4.7	3.9
47.	5.1	4.4	47.5	5.17	4.39	47.5	5.2	4.35
51.	5.6	4.78	51.	5.62	4.7	51.	5.6	4.73

30 cycles.			25 cycles.		
Amp.	K . W .	Volts.	Amp.	K . W .	Volts.
10.5	1.62	.62	10.5	1.1	.56
14.6	1.5	1.3	14.6	1.5	1.25
19.2	2.08	1.7	19.2	2.1	1.72
24.	2.62	2.15	24.	2.63	2.18
28.8	3.18	2.6	28.7	3.2	2.65
33.	3.7	3.	33.2	3.7	3.07
38.	4.23	3.5	37.6	4.2	3.58
42.4	4.8	4.	42.5	4.8	4.
46.8	5.3	4.5			

1900			1901			1902			1903			1904			1905			1906			1907			1908			1909			1910			1911			1912			1913			1914			1915			1916			1917			1918			1919			1920			1921			1922			1923			1924			1925			1926			1927			1928			1929			1930			1931			1932			1933			1934			1935			1936			1937			1938			1939			1940			1941			1942			1943			1944			1945			1946			1947			1948			1949			1950			1951			1952			1953			1954			1955			1956			1957			1958			1959			1960			1961			1962			1963			1964			1965			1966			1967			1968			1969			1970			1971			1972			1973			1974			1975			1976			1977			1978			1979			1980			1981			1982			1983			1984			1985			1986			1987			1988			1989			1990			1991			1992			1993			1994			1995			1996			1997			1998			1999			2000			2001			2002			2003			2004			2005			2006			2007			2008			2009			2010			2011			2012			2013			2014			2015			2016			2017			2018			2019			2020			2021			2022			2023			2024			2025			2026			2027			2028			2029			2030			2031			2032			2033			2034			2035			2036			2037			2038			2039			2040			2041			2042			2043			2044			2045			2046			2047			2048			2049			2050			2051			2052			2053			2054			2055			2056			2057			2058			2059			2060			2061			2062			2063			2064			2065			2066			2067			2068			2069			2070			2071			2072			2073			2074			2075			2076			2077			2078			2079			2080			2081			2082			2083			2084			2085			2086			2087			2088			2089			2090			2091			2092			2093			2094			2095			2096			2097			2098			2099			2100			2101			2102			2103			2104			2105			2106			2107			2108			2109			2110			2111			2112			2113			2114			2115			2116			2117			2118			2119			2120			2121			2122			2123			2124			2125			2126			2127			2128			2129			2130			2131			2132			2133			2134			2135			2136			2137			2138			2139			2140			2141			2142			2143			2144			2145			2146			2147			2148			2149			2150			2151			2152			2153			2154			2155			2156			2157			2158			2159			2160			2161			2162			2163			2164			2165			2166			2167			2168			2169			2170			2171			2172			2173			2174			2175			2176			2177			2178			2179			2180			2181			2182			2183			2184			2185			2186			2187			2188			2189			2190			2191			2192			2193			2194			2195			2196			2197			2198			2199			2200			2201			2202			2203			2204			2205			2206			2207			2208			2209			2210			2211			2212			2213			2214			2215			2216			2217			2218			2219			2220			2221			2222			2223			2224			2225			2226			2227			2228			2229			2230			2231			2232			2233			2234			2235			2236			2237			2238			2239			2240			2241			2242			2243			2244			2245			2246			2247			2248			2249			2250			2251			2252	
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EUGENE DITZGEN CO., PHILADELPHIA

EUGENE DIEZGEN CO., CHICAGO



SCHEME #2. THREE-PHASE.

Three- Phase.

Method:-

Determination of the drop in the pipe when three wires and three-phase currents were used with balanced load.

The apparatus used for the determination of the above was connected as shown in scheme #2 given on the preceeding page. Three leads of number fourteen rubber- covered copper wire each seventy-five feet long were placed in seventy-five feet of one and one eighth inch conduit. These are represented in the scheme as extending from points 1-2; 3-4; and from 5-6 respectively. Points 1-3-5- represent a universal switch by means of which the ammeter and wattmeter could be placed in series with any one of the lines.

There were two pressure terminals on this switch. One of these pressure terminals was connected in series with a sliding contact which could be rotated , making contact with either of the other phases as was desired. A delta connection was used on the lamp racks as shown in the scheme.

Care was taken to keep the load balanced , one bank of lamps on each rack being placed in the circuit for each reading. The pressure over each phase was maintained constant at one hundred and ten (110) volts and loads of from ten to fifty-five amperes were used.

Simultaneous readings of ammeter, voltmeter, and electro-dynamometer were taken for each load with the wires in the pipe and at the different frequencies.

The wires were then taken from the pipe and the experiment repeated , readings being taken with the different loads and frequencies as before.

Three-phase . Wire in the pipes.

60 cycles.

55 cycles.

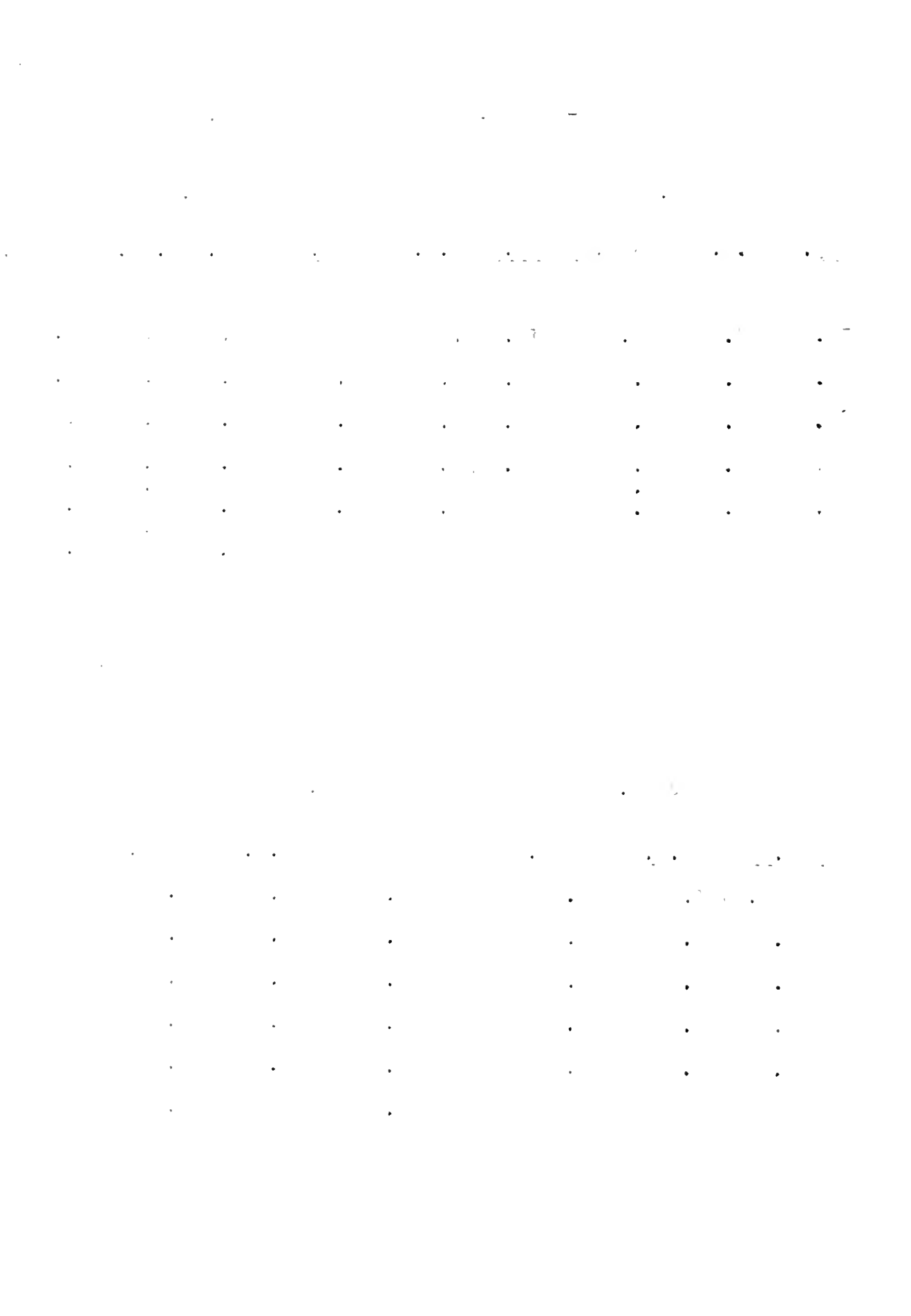
50 cycles.

Amp.	K.W.	Volts.	Amp.	K.W.	Volts.	Amp.	K. W.	Volts.
17.8	1.55	1.35	18.	1.6	1.34	17.4	1.55	1.52
25.	2.25	2.	25.8	2.4	2.12	25.8	2.31	2.08
33.	3.1	2.84	33.8	3.3	2.84	33.	3.06	2.8
40.	3.8	3.55	45.7	4.3	4.05	40.5	3.7	3.42
		4.24					4.31	
47.2	4.53	4.24	51.5	4.7	4.75	47.5		4.13
							5.	
						54.		4.9

30 cycles.

25 cycles.

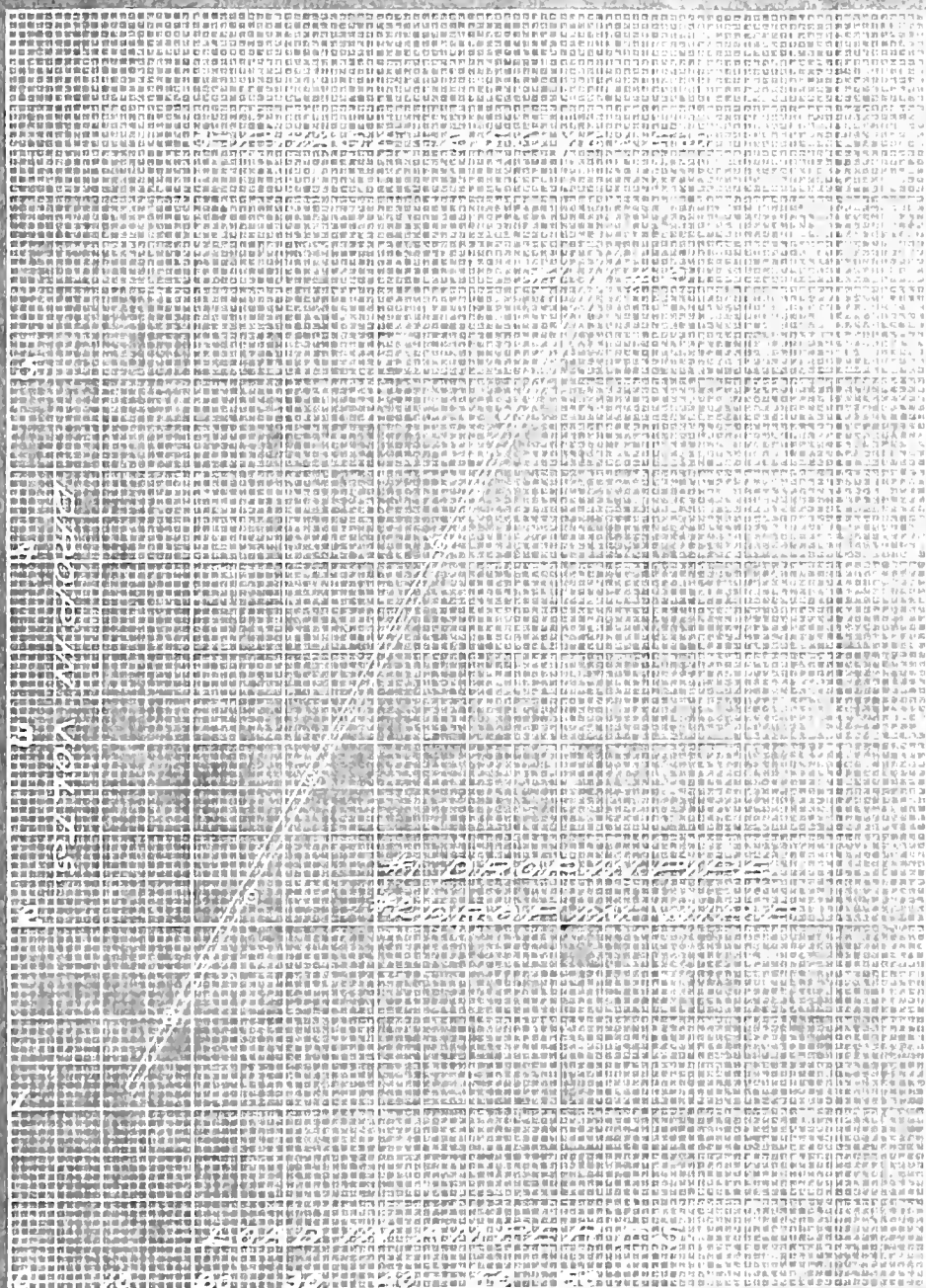
Amp.	K .W.	Volts.	Amp.	K .W.	Volts.
17.4	1.55	1.52	17.4	1.55	1.5
25.5	2.32	2.09	25.4	2.31	2.04
33.	3.05	2.78	33.	3.05	2.8
40.	3.68	3.42	40.	3.7	3.41
46.8	4.27	4.06	47.	4.3	4.08
			54.	5.	4.8

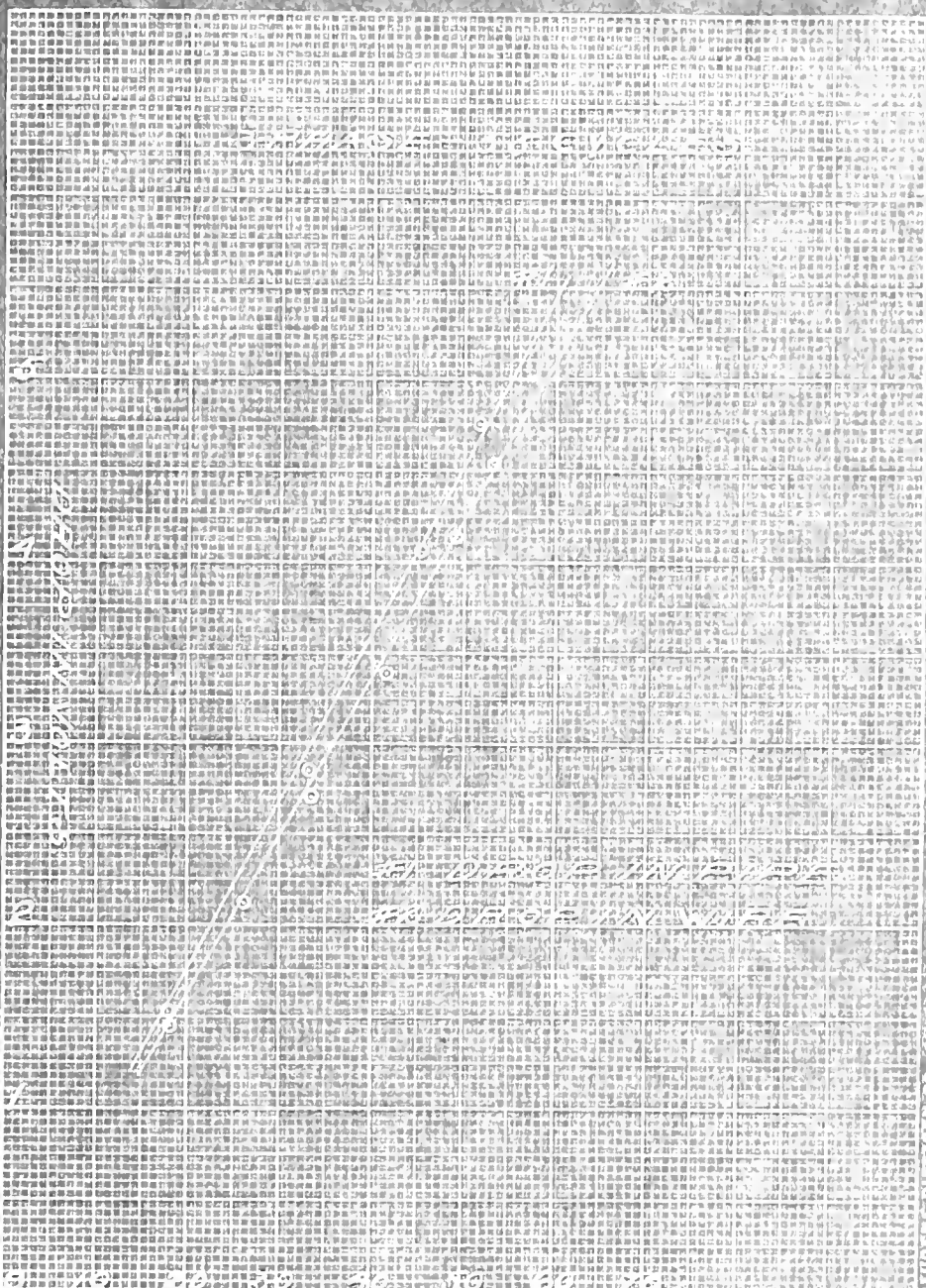


Three-phase Data. Wire out of the pipes.

60 cycles.			55 cycles.			50 cycles.		
Amp.	K . W.	Volts.	Amp.	K.W.	Volts.	Amp.	K.w.	Volts.
18.	1.6	1.38	18.	1.6	1.46	12.6	1.65	1.28
26.	2.38	2.	26.5	2.4	2.1	25.7	2.4	2.
33.8	3.15	2.6	34.	3.22	2.7	33.2	3.24	2.6
42.	3.92	3.4	42.	4.	3.38	40.6	3.97	3.2
49.5	4.75	4.12	49.	4.7	4.15	47.8	4.7	3.9
56.2	5.37	4.82	53.2	5.22	4.55	55.2	5.45	4.64

30 cycles.			25 cycles.		
Amp.	K . W	Volts.	Amp.	K . W .	Volts.
17.8	1.6	1.5	18.	1.6	1.5
26.6	2.4	2.1	26.2	2.4	2.14
34.	3.2	2.78	34.	3.2	2.78
42.	3.9	3.48			
49.2	4.7	4.2			
57.3	5.52	5			





EFFECT OF FREQUENCY ON LINE DROP WITH CONSTANT LOAD/

Cycles.	Single- Phase.		
	.40 Amperes.	45 Amperes.	50 Amperes.
	Volts.	Volts.	Volts.
25	3.86	4.4	4.92
30	3.88	4.42	4.94
50	3.91	4.45	4.97
55	3.92	4.48	5.
60	3.94	4.5	5.02

Three- Phase.

Cycles.	40 Amperes.	50 amperes.
	Volts.	Volts.
25	3.5	4.35
30	3.53	4.4
50	3.55	4.45
55	3.57	4.5
60	3.58	4.52

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L'ESPRESSO 21-10-1972

...e di un'azione di "guerra di posizione" che si svolgeva in un'atmosfera di tensione e di attesa. La situazione era complessa e delicata, e ogni mossa poteva avere conseguenze decisive. I rapporti tra le diverse fazioni erano tesi e instabili, e la ricerca di una soluzione pacifica sembrava un obiettivo sempre più lontano. In questo contesto, l'azione di "guerra di posizione" assumeva un'importanza fondamentale, diventando il mezzo principale per esprimere le proprie posizioni e influenzare l'andamento degli eventi. La lotta si svolgeva su un terreno di confine, dove le regole erano spesso scritte d'accordo e dove la forza non era l'unico criterio di giudizio. La situazione era caratterizzata da una continua evoluzione, con nuove alleanze e rotture che si susseguivano con rapidità. L'obiettivo era di raggiungere una posizione di equilibrio, ma la strada era piena di ostacoli e di insidie. La lotta si svolgeva in un'atmosfera di incertezza e di suspense, dove ogni parola e ogni gesto erano interpretati con attenzione. La situazione era complessa e delicata, e ogni mossa poteva avere conseguenze decisive. I rapporti tra le diverse fazioni erano tesi e instabili, e la ricerca di una soluzione pacifica sembrava un obiettivo sempre più lontano. In questo contesto, l'azione di "guerra di posizione" assumeva un'importanza fondamentale, diventando il mezzo principale per esprimere le proprie posizioni e influenzare l'andamento degli eventi. La lotta si svolgeva su un terreno di confine, dove le regole erano spesso scritte d'accordo e dove la forza non era l'unico criterio di giudizio. La situazione era caratterizzata da una continua evoluzione, con nuove alleanze e rotture che si susseguivano con rapidità. L'obiettivo era di raggiungere una posizione di equilibrio, ma la strada era piena di ostacoli e di insidie. La lotta si svolgeva in un'atmosfera di incertezza e di suspense, dove ogni parola e ogni gesto erano interpretati con attenzione.

CALIBRATION OF INSTRUMENTS.

Weston Wattmeter.
#1791

WATTS.

True	Indicated
1	1
2	2.02
3	3.01
4	3.98
5	5.04
6	6.02
7	6.98
8	8.04
9	9.04
10	10.08
11	11.07

THOMSON A. C. AMMETER.
#70511
AMPERES.

True	Indicated.
10.	10
17.	15
21.5	20
26.5	25
31.	30
36.8	35
41.	40
46.	45
50.2	50
55.	55
60.	60

QUEEN ELECTRODYNAMOMETER. (0-5)

VOLTS	
True	Indicated.
1.	.98
1.5	1.47
2.	1.98
2.5	2.48
3.	2.99
3.5	3.5
4.	4.
4.5	4.5

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EVAENE DITZOLD CO., CHICAGO

Explanation of data and curves.

Curves were platted from the data obtained to show graphically the difference between the drop over the wire when in the conduit and when outside of it.

The curves on pages ten to fourteen inclusive were platted from data taken with single-phase current. Curve #1 being the drop over the wire in the pipe and curve #2 showing the drop over the wire when the conduit was not used. In the same way the curves on pages twenty to twenty-four were platted from the data taken with three-phase current.

The data on page twenty-five showing the effect of frequency on line drop was taken from the curves of variable load. From this data the curves on pages twenty-six and twenty-seven were platted.

The instruments used were carefully and accurately calibrated and curves platted from the data obtained and included in this paper on pages twenty)Nine to thirty-one inclusive.

DISCUSSION.

By a comparison of the data and the curves previously given it can be seen that the iron conduit has a very marked effect upon the difference of potential over the wire, increasing it very noticeably.

This increase in apparent resistance would be too small in value to be read on the average central station instrument. It is even very small when compared with the ohmic resistance of the wire.

From the data and curves of the single and three-phase currents, the authors find that the self-induction due to the use of the iron conduit has a greater effect for single phase currents. With the three-phase current and three wires in the conduit the fields caused by the current in the separate conductors would oppose each other. Since the currents are not in the same phase and therefore do not reach a maximum at the same time their fields neutralizing each other cutting down the self-induction.

The effect of different cyclic speeds was compared and it was found that the effect of self-induction increased directly as the frequency. The effect also increased directly as the load.

The same length of wire in the conduit was used in each case and the temperature at which the readings were taken

was kept as uniform as possible.

The wire used is the smallest wire found in construction work and the most available for this investigation. It furnishes a sample of what the effect would be if larger wire were used and a proportionately larger current.

With a load of fifteen amperes which is about the normal load for number fourteen wire on covered work the increased load at sixty cycles single phase is about one tenth of a volt. The ohmic drop at this load was one and two tenth volts making the drop due to self-induction one twelfth of the ohmic drop.

The effect of self-induction would increase directly with the length of the iron conduit used, and one tenth of a volt for seventy five feet would mean .133, volts per hundred feet or 1.33 volts per thousand feet.

With of fifteen amperes and sixty cycles with three phase currents the difference in voltage was .08 for seventy five feet of wire. This made the inductive drop on fifteenth of the ohmic drop. The drop per hundred feet would be .106 volts and per thousand feet of wire in the conduit would be 1.06 volts.

The induction of the wire in the conduit would be increased if where there are a number of circuits different wires of different phases put together. To avoid this it is wise to see that wires of the same phase are put in the same pipe and thus cut down the

effect of induction to a minimum. This is especially true in the wiring of large buildings.

If the wire is wound together as tightly as possible the induction will be reduced as well as the capacity of a pipe increased. With concentric wires the effect of self-induction will be reduced to zero. The induction in the wire besides causing an increase drop in potential would also cause a large amount of heating of the iron which might reach dangerous limits if not reduced.

FINIS.

